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SZAIBELYITE FROM LINCOLN COUNTY, NEVADA.

J. L. Gillson and Earl V. Shannon[1]

The borate mineral szaibelyite, or szajbelyite, found originally as radiating grains in a metamorphic limestone associated with ludwigite, in the Werktal at Rezbanya, in Hungary, has been found in a similar occurrence in a contact-metamorphosed limestone, about ten miles west of Pioche, Lincoln County, Nevada.

In the course of the field study of the Pioche, Nevada, district, Doctors Westgate and Gillson of the U. S. Geological Survey found a small copper prospect at the contact of a limestone with a quartz monzonite in the so-called Blind Mountain mineral district. Attracted by the exceptional abundance of the mineral ludwigite in the rock on the dump of the prospect, a number of specimens were collected. In their subsequent examination veinlets of a very acicular mineral were found cutting a magnetite-serpentine-ludwigite rock. A chemical analysis in the U. S. National Museum of material from the veinlets served to identify the acicular mineral as szaibelyite.

The exact location of the copper prospect can be found by reference to the Bristol, Nevada, topographic sheet of the U. S. Geological Survey. Blind Mountain is near the south margin of the sheet, and near its center in an east-west direction. It is a sharply pointed knob, around the summit of which the 7,700 foot contour closes in a very small circle. The summit is exactly 1.05 miles S. 44° W., from the Bench Mark 8,928 on the crest of the Bristol Range. The prospect at which the borate minerals occur, lies just one-half mile S. 65° W. from the summit of Blind Mountain, and on the northeast slope of a low hill of quartz monzonite which is itself not high enough to show on the topographic map.

The limestone around the monzonite mass is marmorized over a considerable area, but a strong development of silicates occurs only very locally. At the prospect the rock is not well exposed except on the face, where a banding of black ludwigite-magnetite-serpentine rock and a diopside-spinel rock is found. The igneous contact is probably within twenty feet. The copper stain which had attracted the prospector has been caused by alteration of a small amount of bornite present in the serpentine rock.

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[1] Published by permission of the Director of the U. S. Geological Survey, and the Secretary of the Smithsonian Institution.

The szaibelyite occurs as disseminated grains and veinlets in the black banded material. The banding is in that peculiar sub-spherical, concentric manner not uncommon in certain contact-metamorphic deposits. The country rock is a white granular dolomite marble from which all of the original sedimentary character has been eliminated.

The sequence of the minerals forming in the marble is difficult to determine with certainty, but it is most probable that the szaibelyite is a late metamorphic mineral, and is not as supposed by M. Löw[2] to be a weathering product of ludwigite. Later minerals to form than the szaibelyite were hydromagnesite, brochantite and calcite. The hydromagnesite had formed along joint cracks as large clear crystalline masses. When observed under the microscope between crossed nicols the grains of hydromagnesite exhibit the twinning lamellae described by Rogers.[3]

Very considerable difficulty was encountered in separating the acicular szaibelyite from another needle-like mineral with which it is intergrown. Furthermore, all attempts to make a concentrate of this second and less abundant mineral for analysis, failed, and it remains unidentified. Its properties are as follows: uniaxial, optically negative, with indices of refraction, $\epsilon=1.527$, $\omega=1.561$.

Mineralogical data on the szaibelyite from Lincoln County, Nevada are: hardness 3 to 4; specific gravity, determined in liquids standardized by a Westphal balance, 2.76 at 22°C.; color, white, but on exposure becomes brownish; uniaxial, optically negative, $\epsilon=1.575$ and $\omega=1.650$. Index of refraction measurements were made in white light and have an accuracy of $\pm .003$. The mineral is fusible, but not readily soluble in acids.

Data on the original mineral given in Hintze[4] and Larsen[5] give indices of 1.59 and 1.65, a specific gravity of 3.0 and a similar hardness. Larsen gives the mineral as uniaxial but states that the mineral is soluble in acid. The Nevada material, however, after boiling a considerable time in acid to eliminate the dolomite was not optically or visibly affected.

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[2] Quoted in Hintze, Carl: Handbuch der Mineralogie, erster Band, neunzehnte Lieferung, p. 96, Berlin und Leipzig, **1921.**

[3] Rogers, A. F.: The crystallography of hydromagnesite: *Am. Jour. Sci.*, (5) vol. **6**, 37-47, **1923.**

Dana[6] gives the mineral as optically biaxial. The acicular fibers of the Nevada material can be turned upon end in a viscous medium and give an interference figure strictly uniaxial.

The chemical analysis of the Nevada szaibelyite was made on a very small amount (0.0476 grams) of material, and on a sample containing only about 90 per cent of szaibelyite and 10 per cent of the unidentified splintery mineral. The results are only the best possible estimations obtainable upon a sample of such size and quality. The silica and lime are probably foreign to the szaibelyite, but the ferric iron seems to belong in the mineral, probably as an isomorphous replacement of B_2O_3. A qualitative test on carefully picked material gave a strong reaction for ferric iron. Dana gives the formula as probably $4\,MgO.3B_2O_3.MgOH+H_2O$.

ANALYSIS OF NEVADA SZAIBELYITE, (Earl V. Shannon)

(Compared with analyses of original material[7])

	Nevada Szaibelyite	Hungarian Szaibelyite	
SiO_2	4.83	0.20	....
Al_2O_3	0.63	....	....
Fe_2O_3	4.21	1.66	3.20
B_2O_3	*(31.22)**	36.66	34.60
CaO	1.26	....	....
MgO	46.72	52.49	49.44
H_2O+	9.87	6.99	12.37
H_2O-	1.26	....	....
Cl_2	....	0.49	0.20
	100.00	98.49	99.81

* By difference

The Lincoln County, Nevada, occurrence of szaibelyite is interesting because of the abundance of boron indicated in a very small mass of rock. At least twenty tons of rock rich in ludwigite lie scattered on the dump of the copper prospect, and the szaibelyite is very common in many of the pieces.

[4] Hintze, Carl: *Op. cit.*, p. 96.

[5] Larsen, E. S.: The microscopic determination of the non-opaque minerals: *U. S. Geol. Survey*, Bull. **679**, 197, (**1922**).

[6] Dana, E. S.: The system of mineralogy, 6th Ed., p. 878, (**1914**).

[7] Analyses taken from Hintze, Carl: *Op. cit.*, p. 96.

A TABULATION OF THE ALUMINIUM SILICATE MINERALS.

Edgar T. Wherry, *Bureau of Chemistry, Washington, D. C.*

The usual form of triangular diagram employed in plotting mineral analyses has certain inconvenient features, such as the difficulty of purchasing printed triangular coördinate paper with suitable spacings, the necessity of recalculating the analytical data or of laying off lines representing partial amounts across the corners of the triangle, etc. A modification which the writer has found useful in the study of minerals with three essential components is here described.

On two axes of ordinary rectangular coördinate paper lay off percentages from zero to 100, and draw a diagonal line connecting the two 100 points. From the common zero point draw a perpendicular to the diagonal line, and on this medial axis lay off percentages starting with the zero of the others as 100, and ending with zero at the intersection with the diagonal line. Then, when two of the components of the mineral series to be plotted are laid off with reference to the rectangular axes, the third component becomes entered automatically on the medial one.

In the case of the aluminium silicate minerals, the diagram is most conveniently placed so that the medial axis lies horizontal, with the portion corresponding to more than 50 per cent on that axis left blank for the insertion of mineral names. This plan has been followed in figure 1, alumina, together with other sesquioxides and with any dioxides present, being plotted along the upper axis, silica plus titania along the lower one, and the remainder, comprising water and alkalies, taking up its place on the medial axis. Variation in silica-alumina ratio then leads to shifting the position of a given mineral up and down; while variation in water content moves it right and left along lines diverging at small angles from the medial axis.

In order to decide which ratios are probably fundamental, a harmonic series of numbers, such as have been used with marked success in crystallography and other fields of science by Professor Victor Goldschmidt, was applied; there being about seven important ratios concerned, the series N_3 was the one selected. By considering the ratio of silicon to aluminium atoms (instead of oxides) the well-known halloysite-kaolinite group could be brought into medial position. For completeness, the end-minerals have been included, in parentheses.

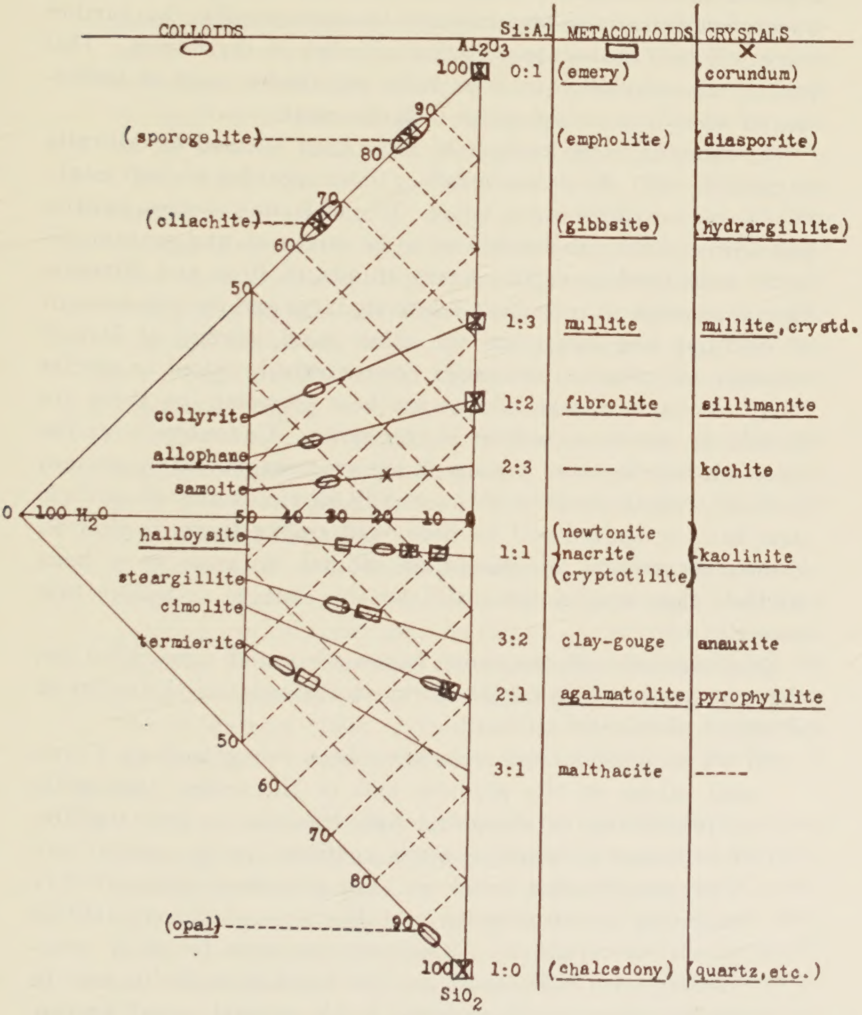

FIG. 1

Many of the recorded analyses of clay minerals fall fairly near the lines corresponding to the members of this harmonic series. Most of them not having been made on optically homogeneous materials, however, the status of some of the individual species can not be regarded as settled. Accordingly, while an effort has been made to include a colloidal, a meta-colloidal, and a crystallized representative of each ratio (indicated in the figure by an ellipse, a rectangle and a cross respectively) it is quite possible that further work will lead to re-interpretation of some of the names. This preliminary tabulation is, then, to be regarded as only an indication of what is to be looked for in future work.

The minerals to be recognized have been selected as critically as possible with the data available; those regarded as well established are underlined in the figure. Two of Dana's species, bauxite and schroetterite, are considered to be mixtures, and montmorillonite is omitted, since the recent studies of Ross and Shannon have shown that it contains a relatively large and definite amount of essential magnesia. On the other hand, several of Dana's varieties and relatives of species are tentatively raised to species rank. No new mineral names are here proposed, as there are already far too many extant in this series. Undoubtedly as the materials bearing these various names are re-examined by modern methods, representatives of practically all ratios and all particle sizes here recognized will be discovered among them; if after all known occurrences of aluminium silicate minerals have been studied, gaps remain, then will be the time to introduce new names.

Brief comments on the names here made use of seem called for; they are presented in tabular form, in the order of the ratios of silicon to aluminium atoms:

0:1 Two colloidal minerals have been recognized by Cornu and others at the alumina end of the series, sporogelite corresponding to diasporite and cliachite to hydrargillite; their separate existence needs confirmation by optical and X-ray examination, however. The anhydrous metacolloid is commonly known as emery, and the corresponding crystallized mineral as corundum. Diasporite has been found in metacolloidal form in Missouri, and the Swedish empholite may be similar; the crystallized form of this mineral is well known. The alleged dimorphous form "kayserite" needs confirmation. There has long been a dispute as to the nomenclature of the more hydrous minerals, simply settled here by recognizing as distinct species the metacolloidal gibbsite and the crystallized hydrargillite.

1:3 Collyrite may well be the colloidal representative of this ratio, the more complex formula often given being based on poor analyses of poorer material, and so unworthy of acceptance. This name has priority over schroetterite, which does not appear essentially different. One of the triumphs of modern methods of mineralogical research has been the recognition of the mineral mullite, an anhydrous member of this group. X-ray study shows it to have essentially the same crystal structure as sillimanite, which is possible, on the atomic-volume theory, if the simplest formula of mullite is tripled and that of sillimanite multiplied by eight, making them respectively $Al_{16}Al_2Si_6O_{39}$ and $Al_{16}Si_2Si_6O_{40}$; as the atoms of aluminium and silicon are similar in dimensions, and oxygen atoms are comparatively small, these two compounds should be capable of taking on closely similar space-arrangements.

1:2 Allophane or allophanite is well known to be the colloidal member. Again a minor dispute as to nomenclature may be settled by recognizing the metacolloid fibrolite and the crystallized sillimanite.

2:3 Dana does not accord to samoite species rank, but it deserves this as much as some other "species," and while awaiting optical study may be placed in the colloidal column opposite this ratio, which it approaches as closely as the dubious character of the material would lead one to expect. The apparently cubic crystallized kochite, while assigned a more complex formula, does not deviate far from the line of this ratio.

1:1 Halloysite is definitely known to be the collodial member of this group, modern analyses on optically examined isotropic material having been made. There appear to be several metacolloidal representatives, ranging from the high-water newtonite thru less hydrous nacrite to the low-water cryptotilite. The last name is given by Dana in the original German form kryptotil, but the Greek *kruptos* is commonly transliterated into English as the syllable *crypt*, and the mineralogical termination *ite* is systematically added to roots ending in *l*, hence the form of the name here adopted. Many china clays, soil colloids, etc., approximate to this aluminium-silicon ratio, and to the water content of cryptotilite. The so-called rectorite appears to be a one-dimensional colloid form of the same mineral, while leverrierite as originally described seems to be a similar material in which the metacolloidal flakes have aggregated themselves into vermicular crystals. The term kaolin has been applied to such varied members and relatives of this group that it is best considered a rock name; kaolinite is the crystallized representative.

3:2 Descriptions of steargillite suggest that it may be the colloidal member of this group, although it needs optical examination. Clay-gouge, as it is called by the miners, such as was described by Larsen and the writer under the heading "leverrierite from Colorado," is apparently more correctly assigned to this group, in which it occupies the place of the metacolloidal member, being actually a one-dimensional colloid. Anauxite has recently been shown to be well crystallized and to fall near this ratio, the single analysis being insufficient proof of greater complexity.

2:1 The colloidal member of this group is apparently cimolite, for although more complex formulas have been assigned to it, optical study has shown the frequent presence of admixed quartz in material like that analyzed. A low-water metacolloidal representative is the well-known agalmatolite, which grades into the crystallized pyrophyllite. Dana's formula for montmorillonite would bring it also into this group, but as already noted it is now known to be a magnesium-bearing mineral, and so is not properly included here.

3:1 Termierite has been described as the colloidal mineral of this ratio, but perhaps needs further study, as it shows some double refraction. The description of malthacite suggests that it may be a meta-colloidal representative, but it requires reinvestigation. No crystallized member has been recognized.

1:0 The minerals opal, chalcedony and quartz, with the other crystalline forms of silica, complete the series.

In conclusion, it may be hoped that this method of tabulation will aid other workers in recognizing what ratios are most probably represented by analyses of aluminium silicate minerals, and that the publication of this note will lead to further work on correlating the chemical and optical properties of members of this mineral series.

A NEW THEORY OF THE COMPOSITION OF THE ZEOLITES. PART III

(*Continued from page 117*)

A. N. Winchell, *University of Wisconsin*

3. The Composition of Chabazite and Related Zeolites

The composition of chabazite is usually given as $(Ca,Na_2)Al_2Si_4O_{12}.6H_2O$, which means that two atoms of sodium may replace one atom of calcium in the crystal space lattice. Since such a change, although apparently possible in artificial alterations of zeolites, and especially of the artificial zeolite known as permutite, is contrary to the condition in all anhydrous silicates, it seems worth while to test the matter somewhat carefully, particularly since it has been found that a different explanation can be applied to thomsonite.[1]

After a careful study of all available analyses, including the ninety-nine listed by Doelter[2] and a few others,[3] it seemed necessary to reduce the number in order to concentrate attention on the best or "superior" analyses. In chabazite and in many other zeolites the ratio of Al_2O_3 to $CaO+Na_2O$ is more constant than any other ratio which can be derived from the analyses, and varies very little from 1:1. By rejecting all the old analyses, and all those not made on selected crystal material and also five analyses in which this ratio was not satisfactory, the thirteen "best" analyses were selected.

The results of plotting these analyses on a square, on which the variables are the Al_2O_3-SiO_2 ratio and the CaO-Na_2O ratio, as described in the discussion of natrolite, are shown in Fig. 3. The distribution of these points seems to the writer to indicate the existence of an isomorphous series along the line ABC which is curved through those points which represent mix-crystals having the same number of Ca+Na atoms, and of Al+Si atoms for a constant number of O atoms. The line represents a series from $Ca_7Al_{14}Si_{26}O_{80}$ at A to $Na_4Ca_3Al_{10}Si_{30}O_{80}$ at C.

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[1] A. N. Winchell: *Am. Min.*, **X,** (1925).

[2] Hdb. Mineralchemie, **II,** 3, 1921, pp. 73-128.

[3] G. T. Prior: *Mineral. Mag.*, **XVII,** 1916, p. 274; and G. Stoklossa: *N. Jahrb. Min., Beil. Bd.* **XLII,** 1919, p. 39.

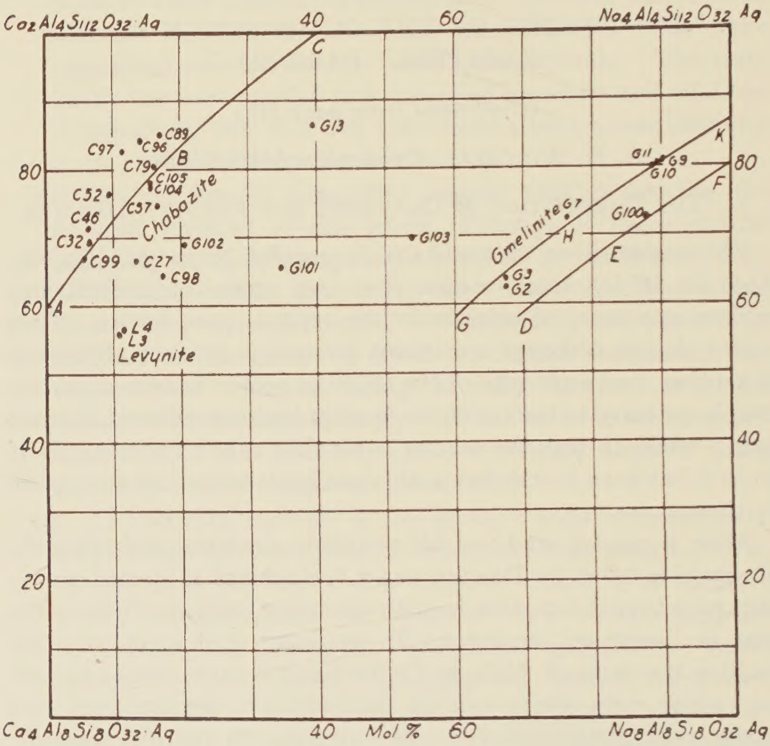

Fig. 3. The Composition of Chabazite and Related Zeolites

Smith, Ashcroft and Prior[4] have recently argued that gmelinite is merely a soda-rich chabazite in spite of the difference in cleavage and in crystal habit. Therefore the composition of gmelinite should be compared with that of chabazite. Unfortunately there are very few modern analyses of gmelinite; in order to obtain enough analyses to show the range in composition it is necessary to use some of the older ones, of course selecting the best of these. In this way eleven analyses were selected which are plotted on Fig. 3. The correct interpretation of the meaning of the distribution of these points is not obvious, but the writer believes gmelinite is

[4] *Mineral. Mag.*, **XVI**, 1916, p. 274.

essentially a series varying in composition along the line DEF,[5] which is curved through those points which represent mix-crystals having the same number of Na+Ca atoms, and of Al+Si atoms, for a constant number of O atoms. The line represents a series from $Na_4Ca_2Al_7Si_{13}O_{40}$ at D to $Na_6Al_6Si_{14}O_{40}$ at F. If this view is correct there is a distinct chemical difference between chabazite and gmelinite, since the former contains 7 Ca+Na atoms for each 80 atoms of oxygen while the latter contains 12 Ca+Na atoms for the same number of oxygen atoms.

There are some analyses which are intermediate between these two conditions; these are responsible for the ordinary view that there is a gradation from chabazite to gmelinite. Such intermediate types are abnormal, as shown by their relative scarcity, and the writer believes that they have nothing to do with a correct interpretation of the normal types. It is possible that they are incorrect on account of faulty execution or methods of analysis, or on account of impurities in the material analyzed. However, some of the intermediate points (for example 101 and 102) represent modern analyses made on carefully selected material For these a different explanation is needed.

It is well known[6] that zeolites can be changed in composition artificially in such a way that a Ca-zeolite can be changed into a Na-zeolite. Such an exchange of bases in zeolites is the foundation of the modern method of water-softening. The exchange of bases is controlled by valence so that, for example, two atoms of sodium enter the zeolite in place of one atom of calcium which goes into the salt solution. At first thought this fact seems to demonstrate that in zeolites isomorphous systems are controlled by valence alone. However, principles which apply to the exchange of bases in crystals already formed do not necessarily apply to the formation of new crystals, that is, the writer believes that in the formation of isomorphous zeolite crystals as in the formation of all other isomorphous crystals *one* atom takes the place in the crystal space lattice of *one* other atom regardless of their respective valences.[7]

The zeolites are exceptional and remarkable because in crystals already formed (perhaps on account of inertia) bases can be exchanged with those in a solution surrounding the crystal under the control of valence, so that two monovalent atoms take the place of one divalent atom, or *vice versa*. This process is fully demonstrated and in current use artificially; there is no reason to doubt its occurrence in nature, though the necessary conditions seem to be uncommon in nature. It is to this process that the writer would appeal to explain the occurrence of crystals of chabazite abnormally rich in soda,[8] and also the occurrence of gmelinite crystals abnormally rich in lime.

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[5] Or, perhaps along a line parallel to DEF and a short distance to the left of it, such as GHK.

[6] I. Zoch: Chemie der Erde, I, 1915.

[7] Of course all valences in each end-member molecule must be satisfied.

In general, exchange of bases in zeolites is facilitated by the presence of much water;[9] that is, those zeolites containing much water exchange their bases more freely than those with less water. Chabazite contains the maximum water content known in zeolites (except for the rare faujasite) followed by minerals of the phillipsite group, gismondite, heulandite, laubanite, mordenite, epistilbite, scolecite, thomsonite, etc.

This theory regarding the constitution of chabazite and gmelinite can be tested at any place where complete information is available regarding the nature of the solutions in which crystals have been immersed.

Levynite is commonly referred to the chabazite group and it is true that a resemblance in axial ratios can be shown. However, the crystal habit is distinctly different and the inferior cleavage of levynite does not correspond with the distinct cleavage of chabazite. The mineral is so rare that the only good analyses are the two made by Hillebrand of crystals from Table Mt., Colo. These are shown in Fig. 3 at L3 and L4. The position of these points shows that levynite is not the same as chabazite nor intermediate between chabazite and gmelinite. It is an entirely distinct and independent species. Crystallographic similarities between it and chabazite do not exist because the two belong to a chemically isomorphous series, but in spite of chemical differences. Chabazite has a ratio of 7 Ca+Na atoms to 80 oxygen atoms while levynite has 8 Ca+Na atoms to the same number of oxygen atoms. The composition of levynite can be expressed quite accurately as $NaAlSi_4O_{10}.5H_2O+4CaAl_2Si_3O_{10}.5H_2O$ or $NaCa_4Al_9Si_{16}O_{50}.25H_2O$; no data are available to show whether it is a double salt of this composition or merely a member of an isomorphous series between the limits suggested. Its scarcity perhaps makes the former view the more probable.

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[8] Point 98 is a chabazite abnormally rich in K_2O rather than Na_2O.

[9] I. Zoch; Chemie der Erde, I, **1915**.

4. THE COMPOSITION OF PHILLIPSITE AND RELATED ZEOLITES.

Phillipsite is a zeolite which varies in composition very considerably. The formula is commonly written $(Ca, K_2) Al_2Si_4O_{12}.4.5H_2O$. Without discussing in detail other formulas which have been proposed, it is sufficient to say that, so far as known to the writer, they all involve the theory that Ca and K_2 are equivalent. Since such a condition is contrary to that found in the anhydrous silicates it may be worth while to test the commonly accepted view by the new method recently described.[10]

After a study of all the forty-three analyses listed by Doelter[11] the most accurate were carefully selected by eliminating (1) those made before 1900, and (2) those in which the ratio of Al_2O_3 to CaO+alkalies does not approximate very nearly to 1:1. The twelve analyses thus selected are shown on Fig. 4, which is a diagram entirely similar in construction to that described in the discussion of natrolite. With the exception of two analyses (18 and 19) these indicate clearly that phillipsite is an isomorphous series probably along the line ABC which is curved through those points which represent mix-crystals having the same number of Ca+K atoms, and of Al+Si atoms for a constant number of O atoms. The line represents a series from $K_4Ca_7Al_{18}Si_{22}O_{80}$ at A to $K_{11}Al_{11}Si_{29}O_{80}$ at C. Therefore, in phillipsite, as in thomsonite, chabazite and gmelinite, the isomorphous relationships are between molecules of the same number of atoms of each group, (Ca+Na), (Al+Si), and O.

The analyses of Zambonini[12] are of special importance because they include the least siliceous as well as the most siliceous types as yet fully known. They are also of importance in showing very clearly that the tenor of water decreases markedly in phillipsite with increase in tenor of silica. The decrease is not easily explained, and, in fact, is not recognized in the ordinary view first proposed by Fresenius[13] and adopted by Dana,[14] Groth[15] and others, that phillipsite is an isomorphous series from $R''_2Al_4Si_4O_{16}.6H_2O$ to $R''Al_2Si_6O_{16}.6H_2O$, since the change of two atoms of Si for two of Al makes no important change in volume. The new theory furnishes an excellent reason for the decrease since it recognizes that the more siliceous types contain a corresponding increase of K in place of Ca. The volume of a K atom is nearly twice as great as the volume of a Ca atom; therefore the increase of K atoms leaves decidedly less space to be occupied by water. Including the water, the composition of known phillipsite can be expressed as a series from $K_4Ca_7Al_{18}Si_{22}O_{80}.40 \pm H_2O$ to $K_6Ca_5Al_{16}Si_{24}O_{80}.30 \pm H_2O$.

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[10] A. N. Winchell. The Composition of Thomsonite, *Am. Min.*, **10**, 90, (1925).

[11] Hdb. Mineralchemie, **II**, 3, 1921, pp. 138-150.

[12] F. Zambonini: *Bull. Soc. Fr. Min.*, **XXV**, 1902, p. 360; and Mineral. Vesuv., **1910**, p. 294.

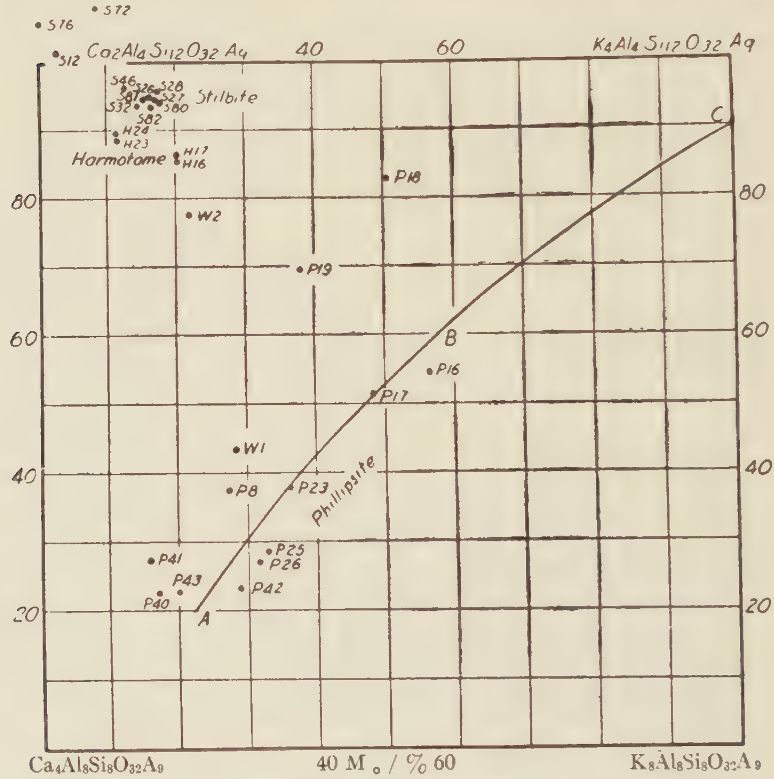

Fig. 4. The Composition of Phillipsite and Related Zeolites

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[13] *Zeit. Kryst.*, **III**, 1880, p. 67.

[14] Syst. Mineral., **1892**, p. 579.

[15] Mineral. Tabel., **1921**, p. 124.

The two analyses which do not lie along this line may owe their peculiar character to faulty execution or methods of analysis or to impurities in the material used for analysis. However, one of them (19) is a very recent analysis of carefully selected material made under Tschermak's supervision and published by him; it seems more likely that the abnormal character of both is, therefore, due to change in composition by partial exchange of bases (Ca for K_2) as more fully explained in the discussion of chabalite.

Stilbite, harmotome and wellsite are crystallographically related to phillipsite.

Some of the best analyses of stilbite are plotted on the figure;[16] they show that the mineral varies very little in composition; it is near $CaAl_2Si_6O_{16}$. but nearly always contains a small and nearly constant amount of soda; the precise formula is not readily determined from data at present available, but is nearly $Na_3Ca_9Al_{21}Si_{59}O_{160}.60H_2O$. The fact that stilbite contains sodium rather than potassium shows that it is not an end-member of the phillipsite series, as has been suggested.

Harmotome analyses are not numerous; two pairs of "duplicates" are shown on the figure: they are not sufficient to show the variations in composition, but suggest a formula of the type of that of stilbite, perhaps $KBa_5Al_{11}Si_{29}O_{80}.25H_2O$.

There are only two analyses of wellsite on record; the first one —made on material from the original locality in North Carolina by Pratt and Foote[17]—seems to be phillipsite with part of its calcium replaced by barium and strontium (which are considered equal to calcium in computing the position of the point (W_1) in the figure.) The other analysis (W_2) by Fersman[18] of a sample from Russia is apparently a lime-rich harmotome rather than wellsite. Wellsite like the potash-rich phillipsites contains relatively little water, since the barium atom like the potassium atom is much larger than the calcium atom.

Incidentally, it may be remarked that the new orientation for phillipsite, stilbite and harmotome recently proposed by Tschermak[19] seems to the writer to be a decided improvement. It is as follows:

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[16] Stilbite contains Na rather than K, so that in reading its composition from the diagram the right hand corners must be assumed to be sodium instead of potassium molecules.

[17] *Am. Jour. Sci.*, III, 1897, p. 443.

[18] *Trav. Mus. Géol. Acad. Sci. St. Petersbourg*, III, 1909, p. 129; *Zeit. Kryst.*, LI, 1915, p. 291.

Dana		Tschermak
001	=	100
010	=	010
100	=	$10\bar{1}$
$\bar{1}01$	=	001
011	=	120
110	=	$12\bar{1}$

With this new orientation the phillipsite group, like all the other fibrous zeolites and many other fibrous minerals, is elongated in the vertical direction instead of parallel to a. Furthermore, the experiments of Rinne[20] on stilbite show that when it becomes orthorhombic at about 250°C. the axes Y and Z coincide with Dana's axes b and a, but X is normal to 001 and not parallel with c. With Tschermak's orientation the orthorhombic substance has $X = a$, $Y = b$, $Z = c$.

(*To be continued*)

A FULGURITE FROM SOUTH AMBOY, NEW JERSEY[1]

W. M. Myers[2] and Albert B. Peck[3]

Fulgurites, the glassy irregular tubes produced by the fusion of sand or siliclous soil, which has been struck by lightning, have attracted attention from very early times. Their rare occurrence, unusual appearance and association with localities where lightning has been observed have lead to many strange conjectures concerning them. Before the true nature of lightning had been established by Franklin, there was even some popular belief that they were the actual "thunder bolts" which descended from the sky.

The infrequency with which fulgurites are encountered together with the difficulty of extracting them from the surrounding soil and the fact that their true identity often is not recognized has resulted in the recovery of very few specimens and many mineralogical museums are without a representative.

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[19] *N. Jahrb. Min.*, 1897, **I**, p. 41.

[20] *Sitz. Akad. Wiss. Wien*, **CXXVI**, 1917, p. 541 and **CXXVII**, 1918, p. 177.

[1] Published by permission of the Director of the Bureau of Mines, Department of the Interior.

[2] Associate Mineral Technologist, Nonmetallic Minerals Exp. Station, Bureau of Mines, New Brunswick, N. J.

[3] Assistant Professor of Mineralogy, University of Michigan.

Through the courtesy of Prof. G. H. Brown, Director of the Department of Ceramics of the State University of New Jersey, the writers have had the opportunity of examining a fulgurite which was found last year at South Amboy, New Jersey. This fulgurite was encountered in the sand pits operated by the Crossman Company during the operations attendant to the removal of the sand for industrial uses. Unfortunately it was badly broken during its removal and few pieces were extracted having a length greater than six inches. This is said to be at least the third fulgurite which has been found in this locality.

The length of the pieces recovered totaled nine feet. It is probable that the original length was in the vicinity of eleven feet. The greatest diameter observed was three inches, which gradually decreased to three sixteenths of an inch. The taper was very gradual and was marred only in a few places by sudden expansions in diameter. Evidence was found of only one branch from the main stem; aside from this the fulgurite originally was one continuous conical rod. The surface was exceedingly rough and covered with excrescences measuring from one-sixteenth to one-half inch in length. The entire surface was coated with partially fused grains of sand. The exterior color varied from yellow and light brown to a dull white. The glass of the interior was an opaque white due to the inclusion of bubbles. Where these were lacking a typical transparent glass was found. Black stained areas, probably due to the presence of iron oxides, were noted in some sections.

The most marked feature of the fulgurite was the hollow core which extended almost its entire length. In places this had been filled with glass; in others it became so pronounced that the fulgurite became a thin shell. At one point where the diameter was three-eighths of an inch, the walls had a thickness of one thirty-second of an inch. Cross sections display a very pronounced radiating structure from this core. Even the included bubbles are elongated and are arranged with their long axes pointing toward the center. These bubbles are so abundantly disseminated throughout the glass that the glass itself is divided into a mass of radiating needles. The gaseous inclusions were so numerous that the specific gravity of the glass was greatly lowered. The apparent gravity, determined with a Jolly balance, showed variations from 1.05 to

1.25, with an average of 1.14. All portions of the fulgurite were exceedingly brittle and could be crushed readily in the hands.

Chemical analysis of a representative section is as follows:

(Analysis by Mr. E. E. Berger)

SiO_2	99.00
Al_2O_3	.70
Fe_2O_3	.30
	100.00

The sand surrounding the fulgurite was composed of quartz grains discolored with a small amount of limonite and containing a small amount of a clay-like mineral. The fulgurite appears to be the product of the direct fusion of these materials. Typical sections were examined with the petrographic microscope to determine what changes in mineral composition had taken place.

The bulk of the fulgurite was found to be composed of an isotropic glass having an index of refraction of 1.462 ± 0.003, typical of silica glass. No difference was observed from the center toward the outer edge except in the number of bubbles. A few areas of parallel needles possessing high index, parallel extinction, and positive elongation were found to be present in places. These are probably the mullite ($3Al_2O_3.2SiO_2$) of Bowen.[4] The grains adhering to the exterior of the fulgurite were found to have a quartz center surrounded with a fine grained border of cristobalite. The enormous energy liberated by lightning, sufficient to fuse quartz, would undoubtedly be sufficient to dissociate any clay-like mineral and recombine its alumina content with quartz, forming mullite.

Much room is left for conjecture concerning the mechanics of the formation of a fulgurite. A bed of sand with its comparatively uniform mineral composition and corresponding uniform electrical resistance, composed largely of one mineral readily fusible at the temperature attained, presents ideal conditions. At least fulgurites from other sources are rare, although a similar phenomena caused by lightning striking rocks has been reported. The tube-like structure may be due in part to the sudden cooling which must have been rapid or glass would not have resulted. It may also be due to the fact that the volume of sand which was fused to glass must have been much greater than the volume of the resultant glass, leaving a crude cylindrical mould to whose sides the glass was drawn by cohesion while in a viscous state. The included bubbles have most probably arisen from moisture entrapped during the sudden fusion of the sand, wet from the storm, or perhaps in part from volatilization of silica or other components into a gaseous form when the bolt struck. The presence of mullite is undoubtedly due to the short time the mass was liquid, thus giving the alumina of the clay insufficient opportunity to be thoroughly disseminated through the silica glass for complete solution. Hence, at points of high local concentration of alumina, mullite was formed.

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[4] Mullite, a silicate of alumina. N. L. Bowen, J. W. Grieg, E. G. Zies, Jr., *Wash. Acad. Sci.*, **14**, 183-191 (1924).

Since the above note was written, Prof. A. F. Rogers has called our attention to the fact that Lacroix has given the name "lechateliérite" to the glass of fulgurites.[5] He does not, however, mention the presence of mullite. Professor Rogers[6] detected water, upon heating in a closed tube a fulgurite containing many bubbles, thus confirming our conclusion that the bubbles are due to entrapped steam.

BOOK REVIEWS

MIKROSKOPISCHE PHYSIOGRAPHIE DER MINERALIEN UND GESTEINE. Rosenbusch-Wülfing, 5th edition, fully revised. Vol. I, First Half, octavo, pages 533–846. The whole volume contains 680 figures and 15 plates. E. Schweizerbart'sche Verlagsbuchhandlung, *Stuttgart*, 1921-1924.

This is the third and last section of volume one. (For reviews of the first two sections see *Am. Min.*, **7**, 211, 1922, and **8**, 172, 1924.

The discussion of the microscope and its uses is completed. The other subjects considered are the use and application of the axial angle apparatus and of the conoscope; investigation of cohesion and density; methods of separation; and chemical methods. The morphological features of crystals are treated in four chapters as follows: (a) Formation, (b) Inclusions, (c) Aggregates, and (d) Deformations. The appendix includes tables of indices of refraction, birefringence, and specific gravities, as also plates of photomicrographs of thin sections of rocks and minerals, and of chemical preparations as well. E. H. KRAUS.

THE STRUCTURE OF CRYSTALS. RALPH W. G. WYCKOFF. American Chem. Soc. Monograph Series. Chemical Catalog Company. 19 East 24th St., *New York*, 1924. 462 pp. 231 fig. Price $6.00 net.

This book consists of two parts; the first dealing with theory and methods, the second with results.

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[5] *Bull. Soc. Fr. Min.*, **38**, 182-6 (1915).

[6] *Jour. Geol.*, **25**, 526 (1917).

The first part contains chapters on crystallography, X-rays, interaction of X-rays and crystals, and methods of analysis. These latter chapters are especially excellent. Various types of apparatus are described, and the application of the results is illustrated by actual examples. Beginners, and even older workers in this field will find them helpful. The chapter on crystallography, in spite of excellent figures, seems to lack clearness. It seems as though no one has yet been able to present crystallography, as applied to crystal structure, in a manner intelligible to the average reader. The chapter on X-rays is brief, though it gives the essentials required for crystal analysis. That on the interaction of X-rays and crystals is rather difficult, but formulae are given which can be used even though they are not fully understood.

The second part consists of a bibliography, a review of all structure determinations, and equally important, a critical comment as to the validity of these determinations. This will be of great value to workers who have been unable to keep up with the rapidly accumulating literature of the past few years.

This book will be very welcome to all those who are interested in this new field, for it fills a gap which has existed in the literature in the English language.

L. S. Ramsdell.

X-RAYS AND CRYSTAL STRUCTURE. Sir W. H. Bragg and W. L. Bragg. 4th edition, revised and enlarged. 322 pages. G. Bell and Sons, Ltd., *London*, 1924.

KRISTALLE UND RÖNTGENSTRAHLEN. P. P. Ewald. 327 pages. Julius Springer, *Berlin W-9*, 1923.

The two works cover essentially the same ground, and each costs about the same amount ($6). The first is adapted especially for beginners, while the second is an excellent general reference work covering the whole field uniformly. The Braggs were pioneers in the working out of crystal structure by means of X-rays, and treat the subject in more or less the same order in which it actually developed in the course of their work, keeping in view the mind of the student, and creating a real text-book. Chapter XII, Crystal Analysis and the Atomic Forces, contains much data on the apparent dimensions of atoms not included in previous editions; and XIV, Organic Crystals, brings out in a striking manner how ingenious reasoning can overcome the difficulties inherent in the absence of X-ray diffraction by hydrogen atoms. It can not be said that the conclusions reached in these chapters are final, but the many cases of agreement between prediction and observation show that the right track is being followed. Chapter XVI, which bears no title but is termed a Supplementary Chapter, comprises a summary of some outstanding recent work, although it is not as complete as might be desired. In it a little over three pages is devoted to the space-group method of looking at crystals, with the conclusion that "We may define in terms of space groups or in terms of arrangements, as we please. The latter is more natural to the X-ray methods; and moreover, it tells us more simply and directly what is necessary for the further study of the structure of the crystal."

The second of these works combines many desirable features. The style is easy to follow, the treatment is non-mathematical, and the development of the subject is logical. Contributions to the working out of crystal structure are cordially welcomed, whether based on any particular mathematical viewpoint or not. Both books are well illustrated, and well printed, with surprisingly few typographical errors, and should be on the shelves of every mineralogist's library. W.

NEW MINERALS: NEW SPECIES.

CLASS: SULFO-SALTS. DIVISION: RS: R_2S: Bi_2S_3 = 2 : 1 : 2.

Hammarite

K. Johansson: Bidrag till Gladhammar-gruvornas mineralogi. (Contributions to the Mineralogy of the Gladhammar Mine.) *Arkiv Kemi, Mineral., Geol.*, **9**, No. 8, 11 (1924).

Name: From the locality, Glad*hammar*, Province of Kalmar, Sweden.

Chemical Properties: A sulfobismuthide of lead. Formula, 5PbS. $3Bi_2S_3$. Analysis: Pb 27.40, Cu 7.60, Bi 47.59, S 17.01, insol. 0.04; sum 99.64.

Crystallographic Properties: Perhaps monoclinic. Short prisms or needles. Forms: (100), (010), (110), (210), (120), (230).

Physical Properties: Cleavage, 010, good. Color, steel gray inclining toward red. Fracture, flat conchoidal. High metallic luster. Streak black. H = 3-4. Sp. gr. high.

Occurrence: Found in crystals grown upon drusy quartz at Gladhammar.

Discussion: Although the composition is given as a lead sulfo-bismuthide the mineral contains an appreciable content of copper. If this is calculated as non-isomorphous with the lead the agreement with the formula 2PbS. Cu_2S. $2Bi_2S_3$. (Theory: Pb 25.0, Cu 7.6, Bi 50.1, S 17.3.) is close. This places it in the 3 : 2 division of the sulfo-salts and as the copper analogue of schirmerite.

W. F. Foshag

CLASS: SULFO-SALTS. DIVISION: RS: R_2S: Bi_2S_3 = 2 : 1 : 3.

Lindstromite

K. Johansson: *Op. cit.*; this mineral p. 14.

Name: In honor of G. *Lindstrom*, of the Riksmuseet, Sweden.

Chemical Properties. A sulfo-bismuthide of lead and copper. Formula, 2PbS. Cu_2S. $3Bi_2S_3$. Analysis: Pb 18.95, Cu 5.84, Fe tr., Bi 57.13, S 17.88, insol. 0.20; sum 100.00. Analysis made on selected crystals.

Crystallographic Properties: Prismatic crystals, system unknown. Vertically striated. Forms. (100), (010), (110), (510), (410), (310), (520), (210), (530), (230), (120), (130), (140).

Physical Properties. Color lead gray; luster metallic. Cleavage 100 and 010, good; also prismatic 110. Fracture small conchoidal to uneven. H = 3-3.5. Sp. gr. 7.01.

Occurrence. On quartz in crystals 1 cm. long and several mm. thick.

Discussion. Johansson points out the relation of lindstromite to andorite. This places lindstromite in the 1:1 division of the sulfo-salts. W. F. F.

CLASS: SULFO-SALTS. DIVISION: RS: R_2S: Bi_2S_3 = 2 : 1 : 5.

Gladite

K. Johansson: *Op. cit.*, this mineral p. 17.

Name. From the locality, *Glad*hammar.

Chemical Properties: A sulfo-bismuthide of lead and copper. Formula, 2PbS. Cu_2S. $5Bi_2S_3$. Analysis: Pb 12.40, FeO 0.19, Cu 3.98, Bi 64.96, S 18.04, insol. 0.12; sum 99.69. Analysis on selected crystals.

Crystallographic Properties: Crystals prismatic with the forms (100), (010), (110), (250)?.

Physical Properties: Color lead gray. Streak black. Cleavage 010 good, 100 less so. H = 2-3. Sp. gr. 6.96. Luster metallic.

Occurrence: On quartz crystals with rezbanyite and galenobismutite. Crystals 2 cm. long and 2-6 mm. thick.

Discussion: Gladite is the only member of the 3:5 division of the sulfo-salts. It therefore lies between the livingstonite and the rezbanyite groups. W. F. F.

NOTES AND NEWS

Mr. R. B. Gage of the Testing Laboratory, Trenton, New Jersey, reports on what appears to be a new mineral from Franklin Furnace, New Jersey. The material is similar in chemical composition to glaucochroite except that it contains over three per cent of water. It is light brown in color and occurs with leucophoenecite, bustamite and willemite. Publication will be withheld until additional analyses are made and the mineral has been studied optically.

The latest complete list of The Minerals of Franklin, New Jersey District, compiled by Chas. W. Hoadley and Wm. H. Broadwell, is now ready for distribution. The list, which contains 151 names with references to original descriptions, can be purchased for 10c per copy; postage 1 1/2 c extra. Address Wm. H. Broadwell, 571 Hawthorne Ave., Newark, N. J.

The Walker prize of the Boston Society of Natural History, for the best paper submitted in the field of geology or mineralogy, has been awarded to Edward F. Holden, instructor in mineralogy at the University of Michigan. The paper submitted was entitled "The Pigment of Amethyst."

According to Dr. Charles H. Viol, director of the Radium Research Laboratory of the Standard Chemical Co., less than half a pound (between 200 and 220 grams) of radium has been produced in the world since Madame Curie discovered the element in 1898. When carnotite is used as the source more than 500 tons of ore must be handled to yield one gram of radium. Radon, which is formed from radium, is 160,000 times as active but it loses its activity in about four days. Radon, therefore, can be used only in the treatment of a limited number of patients while radium can be used repeatedly.

Dr. David T. Day, an authority on mineral and petroleum deposits and for many years chief of the division of mining and mineral resources of the U. S. Geological Survey, died in Washington at the age of sixty-five years.

Dr. S. C. Lind has resigned as chief chemist of the Bureau of Mines to become associate director of the Fixed Nitrogen Research Laboratory of Washington, under the direction of Dr. F. G. Cottrell.

Dr. Henry S. Washington, of the geophysical laboratory of the Carnegie Institution of Washington, is in Europe to carry on archeological and volcanological studies in Italy and northern Africa.